EEC 4230 - Mobile Communication Systems

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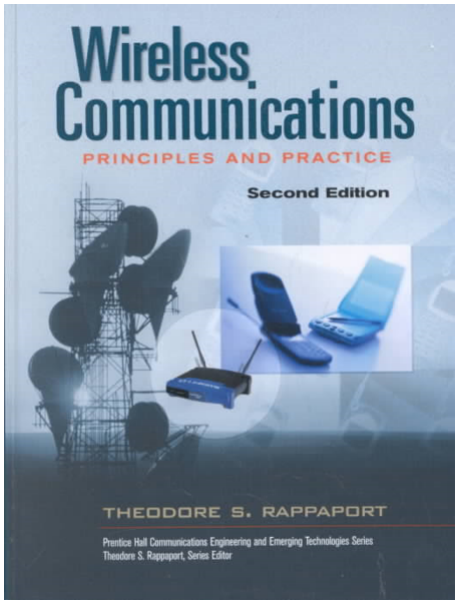
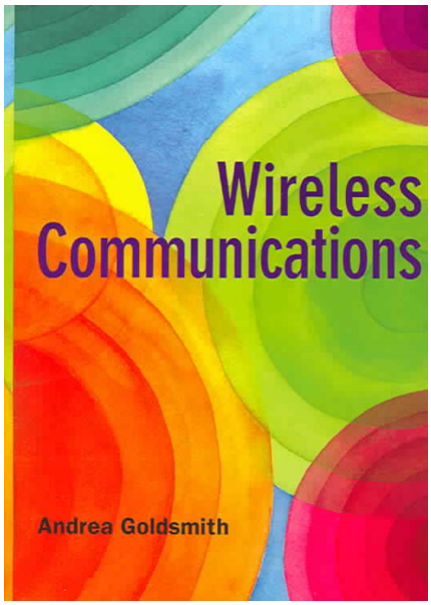
Lecture 1: Introduction and Overview of Mobile Communication Systems

Outline

Course Teaching Materials





Look at the course information and syllabus in pdf format

Introduction

Wireless Systems:

Consist of baseband signal processing, and the Radio freq (RF) transmission / reception stages.

Generations of Wireless Systems:

Several enhancements developed over time (mostly for the base band signal processing at the mobiles and base stations), led to different generations of wireless systems: first generation (1G), second generation (2G), etc...

Radio Propagation:

Effects of environments and propagation media are usually captured into models, which are developed via physical power measurements.

Evolution of Mobile Radio Systems

Studying the **history** of cellular systems can help us understanding the need for system design concepts we have today.

1G Analog Systems

- **1877**: Telephone introduced
- **1897**: First radio communication (England).
- **1946**: First public mobile telephone services
- **1960s**: Bell Lab. developed the cellular concept
- **1970s**: First public mobile telephone of 1946 used non-optimum technologies
- **1979**: World's first cellular system implemented by a Japanese company, Nippon Telephone and Telegraph company (NTT)
- **1981**: In Europe, the Nordic Mobile Telephone system (NMT-450) was developed.
- **1983**: First U.S. analog cellular telephone system, AMPS (Advanced Mobile Phone System).

2G Digital Systems

- **1991**: First U.S. digital cellular (USDC) telephone system, named IS-54. Later upgraded to IS-95 using CDMA technology (2G CDMA)
- **CDMA**: code-division multiple access allows many users (64 users in 2G CDMA) to simultaneously use the same channel, and thus accommodates more users in the system (capacity increase).
- **1990**: Pan European digital cellular standard GSM (Global System for Mobile phone)
- **GSM**: operates on 900MHz band which all of Europe dedicates for cellular services (1800MHz version later introduced). Accepted world-wide

2G Digital Systems

- **1990**: In Japan, NTT upgraded to the Pacific Digital Cellular (PDC) standard to provide digital cellular coverage using a system similar to North America's USDC.
- **2001**: By mid-2001, several major carriers such as AT&T in the US and NTT in Japan announced their decisions to eventually abandon the USDC and PDC standards as long term technology options in favor of emerging standards based on the GSM platform.
- **2001 & above**: Two camps emerge for digital cellular: 2G GSM vs. IS'95 (2G CDMA), and W-CDMA/UMTS (3G-GSM) vs. CDMA2000 (3G evolution for 2G CDMA).
- **Summary**: 1G: analog, 2G: digital, 3G: cdma
- **Mid gen. upgrades:** 2.5G: GPRS, EDGE (GSM+IS-136).

Major Cellular Systems in North America

System	Year of Introduction	Multiple Access	Frequency Band	Modulation	Channel Bandwidth
AMPS	1983	FDMA	824-894 MHz	FM	30 kHz
NAMPS	1992	FDMA	824-894 MHz	FM	10 kHz
USDC (IS-54 or -136)	1991	TDMA	824-894 MHz	$\pi/4$-DQPSK	30 kHz
IS-95	1993	CDMA	824-894 MHz	QPSK	1.25 MHz

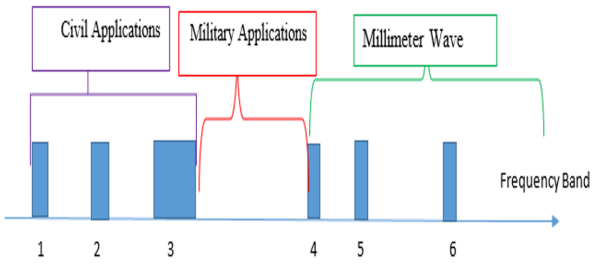
Major Enhancement Features in 1G & 2G

Major Cellular Systems in Europe and Japan

System	Year of Introduction	Multiple Access	Frequency Band	Modulation	Channel Bandwidth
NMT-450	1981	FDMA	450-470 MHz	FM	25 kHz
NMT-900	1986	FDMA	890-960 MHz	FM	12.5 kHz
GSM	1990	TDMA	890-960 MHz	GMSK	200 kHz
NTT	1979	FDMA	400/800 MHz	FM	25 kHz
PDC (similar to USDC)	1993	TDMA	810-1501 MHz	$\pi/4$-DQPSK	25 kHz

Market Penetration of Wireless Services

- **1990**: Less than 5 million cellular subscribers world-wide.
- **2001/2002**: Over 600 million, about 10% of World's population, pay monthly subscription for wireless telephone service by 2001/2002.
- **2010**: It is hoped that the figure will approach 50% of World's population by the end of the first decade of the 21st century (year 2010+).
- **2014**: There ae nearly 7 billion mobile subriptions worldwide!
- **Example of carriers in North America**: AT&T (American Telephone & Telegraph co.) / Bell wireless, Northern Telecom, Rogers Wireless, Verizon, etc.
- **Example of carriers in Egypt:** Vodafone, Orange, Etisalat.



Microwave Bands

1. 900 MHz, 1800 MHz, 2G (GSM).
2. 2100 MHz, 3G (UMTS).
3. 2300 MHz-2600 MHz, 4G (LTE).

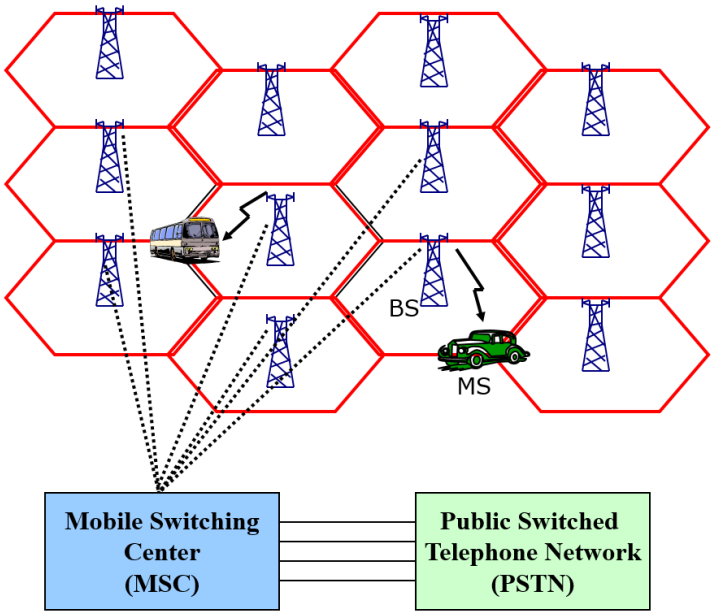
mmWave Bands

1. 28 GHz
2. 38 GHz
3. 72 GHz

Components of Mobile Systems

- A **cellular system** consists of mobile stations (MS), base station (BS), and a mobile switching center (MSC).
- **Mobile Station (MS)**: A station intended for use while in motion or at unspecified locations. It may be a hand-held personal unit (portable) or installed in vehicles (mobile).
- **Base Station (BS)**: A fixed station in a mobile radio system used for establishing wireless communication with mobile stations. It is located at the center or on the edge of a coverage region (called a cell).
- **Mobile Switching Center (MSC)**: Coordinates the routing of calls in a large service area. All BS are connected either by wire or wireless to the MSC via high-capacity link (Microwave relay).
- **Public Switched Telephone Network (PSTN)**: Wired telephone network, connecting homes, businesses, switched centers.

Components of Mobile Systems

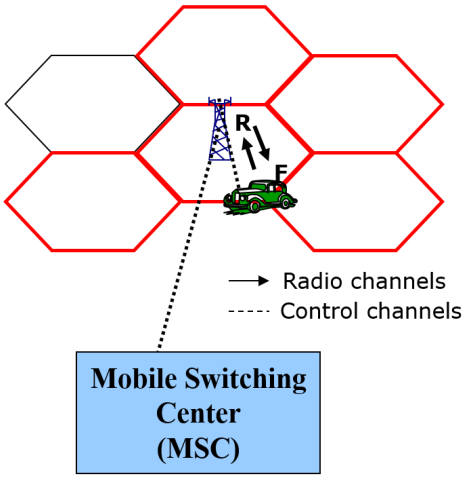


Components of Mobile Systems

- MSC coordinates the activities of all B.S., and connects the cellular system to the Public Switched Telephone Networks (PSTN).
- Typical MSC handles 100,000 subscribers and up to 5,000 simultaneous calls!
- BS links mobile users to the MSC (and thus to the PSTN or world-wide telephone networks).
- Each mobile communicates via radio with one of the BS and may move from coverage of one BS to another during a call, necessitating handoff.
- **Handoff**: process of transferring a mobile from one cell (BS) to another.

The Cellular System

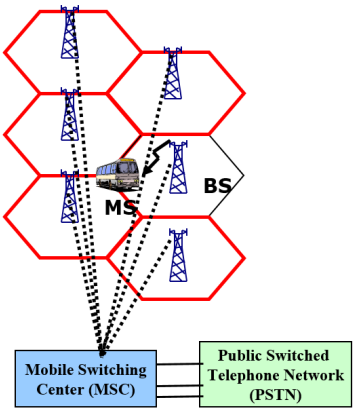
- **Forward channels (FC):** Radio channel used for transmission of information (voice/data) from BS to the mobiles.
- **Reverse channels (RC):** Radio channel used for transmission of information (voice/data) from mobile to the BS.
- **Control channels (CC):** Radio channels used for transmission of call setup, call request, and other control information from BS to mobiles (FCC) or from mobiles to BS (RCC).



The Cellular System

How a cellular phone originates a call?

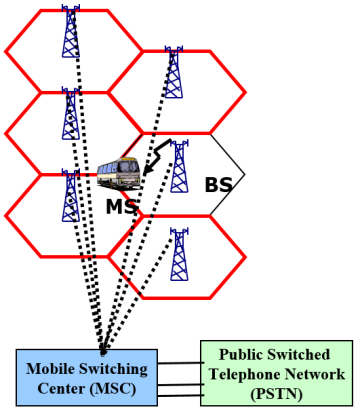
- When a cell phone is turned on, but not engaged in a call, it scans the forward CCs in search for the strongest BS signal and keep monitoring it.
- When a mobile originates a call, a call initiation request (mobile phone number, called telephone number, maximum TX power) is sent to the BS via the reverse CC.
- The BS sends the request to the MSC.
- The MSC validates the request, makes connection to the called party through the PSTN, and instructs the BS and the mobile to move to an unused forward and reverse voice channel to allow the conversation to begin.



The Cellular System

How a cellular phone receives a call?

- When a call is placed to a mobile user, the MSC sends the request to all BS in the cellular system (call request information typically includes mobile id).
- All BS broadcast the mobile identification number over the FCCs throughout the cellular system.
- The mobile receives the message sent by BS which it monitors and identifies itself over the RCC.
- The BS relays the ack and informs the MSC.
- Then, MSC instructs the BS to move the call to an unused voice channel within the cell. The BS assigns a pair of unused voice channel for the communication (forward and reverse), and informs the mobile to change frequencies of operation to those channels.
- A data message (called alert) is transmitted over the forward voice channel to instruct the mobile to ring (alerting mobile user to answer the call).



Roaming Services

It allow subscribers to operate in service areas other than the one from which service is subscribed.

- During a call, the MSC adjusts the transmitted power of mobiles and changes the channels of the mobile unit and BS in order to maintain call quality as the mobile moves in and out of the cell.
- When a mobile enters a city/geographic area that is different from its home service area, it is registered as a roamer in the new service area.
- Every several minutes, the MSC issues a global command (decodable by both local and foreign mobiles), asking unregistered mobiles to report their mobile id. The MSC uses these information to contact home service area of foreign mobiles and get important information such as billing information and roaming service subscription status, from the home location register (HLR).
- If the HLR register indicate that the roaming mobile has subscription for roaming service, the roaming mobile is admitted to the foreign network and allowed to receive and place calls.
- Roaming can be Local or Global.

Major Problems & Challenges

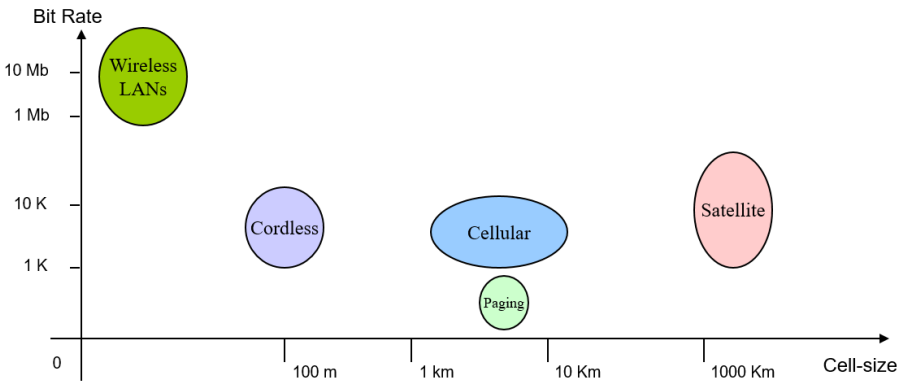
- **Multipath propagation & fading:** due to user mobility, changing environments, and scatterers.
- Coverage Analysis, propagation channel modeling
- **Co-channel interference & noise:** due to presence of other users and nearby cells (or BS).
- Efficient handoffs, channel assignments, and call admission control.
- **Capacity and Quality of service:** how to increase data rate, # of users, without degrading quality ?

- Link quality enhancements through effective coding/modulations, multiple antennas, etc.
- Multiuser access techniques for spectrum sharing.
- Spectrum reuse, etc.

Fixed vs. Mobile Wireless Systems

Fixed: Users are fixed in one location while maintaining wireless connectivity.

Mobile: Users move while maintaining wireless connectivity.



Mobile Station (MS)

Service	Coverage range	Required infrastructure	Complexity	Carrier frequency	Functionality
TV remote control	Low	Low	Low	Infra-red	Receiver
Garage Door Opener	Low	Low	Low	< 100 MHz	Receiver
Paging System	High	High	High	< 1 GHz	Transmitter
Cordless Phone	Low	Low	Moderate	< 100 MHz	Transceiver
Cellular Phone	High	High	High	< 1 GHz	Transceiver

Base Station (BS)

Service	Coverage range	Required infrastructure	Complexity	Carrier frequency	Functionality
TV remote control	Low	Low	Low	Infra-red	Transmitter
Garage Door Opener	Low	Low	Low	< 100 MHz	Transmitter
Paging System	High	High	Low	< 1 GHz	Receiver
Cordless Phone	Low	Low	Moderate	< 100 MHz	Transceiver
Cellular Phone	High	High	High	< 1 GHz	Transceiver

Exercise 1

1. Compare AMPS, NTT and NMT interms of: (a) modulations, (b) multiuser access, (c) data rate per unit spectrum (spectral efficiency), (d) operation cost.
2. Repeat above for: (i) IS-95 vs. GSM, (ii) WiMAX vs. LTE

Exercise 2

1. Classify the following wireless systems (TV Remote control, Garage Door Opener, Paging System, Cordless Phone, Wireless LAN, WiMax System, Satellite Phone, UWB System, Bluetooth) as belonging to the following groups (some may fit into more than one group):

- **Gourp 1**: High Power
- **Gourp 2**: Low Power
- **Gourp 3**: High Speed
- **Gourp 4**: Low Speed
- **Gourp 5**: Wide Area System
- **Gourp 6**: Local Area System